Altitude Physiology
U3004502 / Version 1
07 Dec 2004

SECTION I. ADMINISTRATIVE DATA

All Courses Including This Lesson	**Course Number**	**Version**	**Course Title**
	300-F6	2005	Flight Medic
	6A-61N9D	05	Flight Surgeon Course (Primary)
	6A-61N9D(RC)(P1)	05	Flight Surgeon Course (Primary), Phase I

Task(s) Taught(*) or Supported	**Task Number**	**Task Title**
		INDIVIDUAL
	081-839-5504 (*)	PREVENT EFFECTS OF HIGH ALTTITUDE/HYPOXIA ON PERSONNEL AND EQUIPMENT
	081-CF9-0001 (*)	MANAGE THE PHYSIOLOGICAL EFFECTS OF ALTITUDE

Reinforced Task(s)	**Task Number**	**Task Title**

Academic Hours

The academic hours required to teach this lesson are as follows:

	Resident Hours/Methods	
	3 hrs	/ Conference / Discussion
Test	0 hrs	
Test Review	0 hrs	
Total Hours:	3 hrs	

Test Lesson Number

	Hours	Lesson No.
Testing (to include test review)	1 hr	U3004503 version 1

Prerequisite Lesson(s)

Lesson Number	Lesson Title
None	

Clearance Access

Security Level: Unclassified
Requirements: There are no clearance or access requirements for the lesson.

Foreign Disclosure Restrictions

FD5. This product/publication has been reviewed by the product developers in coordination with the USASAM foreign disclosure authority. This product is releasable to students from all requesting foreign countries without restrictions.

References

Number	Title	Date	Additional Information
0-7817-2898-3	Fundamental of Aerospace Medicine, 3rd Edition		
AR 40-8	Temporary Flying Restrictions Due to Exogenous Factors	17 Aug 1976	
AR 95-1	Flight Regulations	01 Sep 1997	
FM 3-04.301	Aeromedical Training for Flight Personnel	29 Sep 2000	

Student Study Assignments

Study student handout and review reference material listed above.

Instructor Requirements

One primary instructor.

Additional Support Personnel Requirements

Name	Stu Ratio	Qty	Man Hours
None			

Equipment Required for Instruction

Id Name	Stu Ratio	Instr Ratio	Spt	Qty	Exp
COMPU-PR0J OVERHEAD PROJECTOR W/ COMPUTER INTERFACE	1:50		No	0	No
COMPUTER-INSTRUCTOR COMPUTER (CPU) WITH KEYBOARD, INSTRUCTOR USE ONLY	1:50		No	0	No
MONITOR-INSTRUCTOR COMPUTER MONITOR, INSTRUCTOR USE ONLY	1:50		No	0	No
SCREEN-INSTRUCTOR SCREEN PROJECTOR, INSTRUCTOR USE	1:50		No	0	No

* Before Id indicates a TADSS

Materials Required

Instructor Materials:
Altitude Physiology Lesson Plan.

Student Materials:
Altitude Physiology Student Handout.

Classroom, Training Area, and Range Requirements

Ammunition Requirements

Id	Name	Exp	Stu Ratio	Instr Ratio	Spt Qty
None					

Instructional Guidance

NOTE: Before presenting this lesson, instructors must thoroughly prepare by studying this lesson and identified reference material.

The 3hr Altitude Physiology is also taught to the IERW students in aviation.

Proponent Lesson Plan Approvals

Name	Rank	Position	Date
Schwab, Douglas			07 Dec 2004
Bost-Pittman, Carolyn			08 Dec 2004
Campbell, John			09 Dec 2004

SECTION II. INTRODUCTION

Method of Instruction: Conference / Discussion Instructor to Student Ratio is: 1:50 Time of Instruction: 5 mins Media: Large Group Instruction

Motivator

NOTE: Use it, paraphrase it, or develop one of your own. Ensure the motivator gains the students attention, states the need for training, and explains the terminal learning objective.

"Man is not physiologically equipped for exposure to high altitudes. To cope, man must rely on preventive measures and, in some cases, life-support equipment. Although Army aviation primarily involves rotary-wing aircraft flying at relatively low altitudes, aircrews may still encounter altitude associated problems. These may cause hypoxia, hyperventilation, and trapped gas disorders. By understanding the characteristics of the atmosphere, aircrews are better prepared for the physiological changes that occur with altitude changes. As altitude increases, barometric pressure decreases; the ascent and descent themselves can also affect the body. In addition, aircrews need to understand the functions of the human circulatory and respiratory systems."

Terminal Learning Objective

NOTE: Inform the students of the following Terminal Learning Objective requirements.

At the completion of this lesson, you [the student] will:

Action:	Manage the physiological effects of altitude.
Conditions:	While serving as an aircrew member.
Standards:	In accordance with AR 95-1, AR 40-8, FM 3.04-301, and Fundamentals of Aerospace Medicine

Safety Requirements

Safety requirements will be addressed as NOTES:, CAUTIONS: and WARNINGS.

Risk Assessment Level

Low

Environmental Considerations

None **NOTE:** It is the responsibility of all soldiers and DA civilians to protect the environment from damage.

Evaluation

Each student will be evaluated on this block of instruction during the final aeromedical exam. This exam will be conducted on your last training day at USASAM.

Instructional Lead-In

NOTE: Use it, paraphrase it, or develop one of your own.

"Up to this point in your training at the School of Aviation Medicine, you have gained knowledge about aviation medicine and aviation protective equipment. Today, we build on your learning by discussing the effects of altitude on the human body."

SECTION III. PRESENTATION

NOTE: Inform the students of the Enabling Learning Objective requirements.

A. ENABLING LEARNING OBJECTIVE

ACTION:	Identify the physiological zones and the physical divisions of the atmosphere
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301.

1. Learning Step / Activity 1. Provide instruction on the physiological zones and the physical divisions of the atmosphere.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 10 mins
Media: Large Group Instruction

a. Atmosphere

NOTE: The biosphere is that area of our world where life can exist. It includes the atmosphere (air), hydrosphere (water) and lithosphere (earth). All of the atmosphere is not within the biosphere.

(1) Definition - a mixture of gases that surrounds the earth's surface. Consists of a mixture of water vapor and gases that extends from the surface to approximately 1,200 miles. Held in place by gravity, it exhibits few physical characteristics that can be readily observed. Additionally, it shields earth's inhabitants from ultraviolet radiation.

(2) Layers of the atmosphere.

(a) Troposphere

1. Lies closest to the earth's surface.

2. Extends to an altitude of about 30,000 feet at the poles and 60,000 feet at the equator. The difference in altitude is due to the rising heated air at the equator.

3. Domain of weather - winds, turbulence and convection. Temperature lapse rate is 2C/1000 feet.

(b) Tropopause

1. Boundary between troposphere and stratosphere.

2. It has a stable temperature and varies in width.

3. Domain of high winds and highest cirrus clouds.

4. Gradually increases in altitude from the polar regions to the equator.

(c) Stratosphere.

1. Extends upward from the tropopause to about 50 miles from the earth's surface.

2. Characterized by a constant (-55°C) temperature, an absence of water vapor, turbulence, no clouds, and jet streams.

3. Ozone layer at the top.

(d) Ionosphere.

1. Extends from the stratosphere to about 600 miles above the earth's surface.

NOTE: The space shuttle orbits at 160 miles above the earth.

2. Forms a shield around the earth and protects individuals from ultraviolet radiation.

3. Large electron density affects communications.

4. Temperature increases to 1500 C.

(e) Exosphere.

1. Extends from the ionosphere to about 1,200 miles above the earth's surface.

2. Hypothetically true space.

b. Physiological zones of the atmosphere. Man cannot physiologically adapt to all the physical changes of temperature and pressure that occur within the various regions. For this reason, the atmosphere is further divided into three physiological divisions. The primary basis for these physiological zones is the pressure changes that take place in the human body.

NOTE: Point out that human factors, presented later, alters the altitudes of the physiological zones.

(1) Efficient zone.

(a) Extends from sea level to 10,000 feet.

(b) Most individuals are physiologically adapted to this zone.

(c) Oxygen levels within this zone are sufficient for a normal, healthy person without the aid of protective equipment.

(d) Barometric pressure drops from 760mm/hg to 523mm/hg in this zone.

(e) Most Army flights take place in this layer.

(2) Deficient zone.

(a) Extends from 10,000 feet to 50,000 feet.

(b) Noticeable physiological problems, such as hypoxic hypoxia and evolved gas disorders, occur unless supplemental oxygen is used.

(c) Barometric pressure drops from 523mm/hg at 10,000 feet to 87mm/hg at 50,000 feet.

(3) Space equivalent zone.

(a) Extends upward from 50,000 feet.

(b) Without an artificial atmospheric environment, this zone is lethal to humans and death will occur rapidly.

c. Composition of the atmosphere.

(1) Nitrogen (N_2): 78%. Most plentiful gas in the atmosphere. Essential building block of life, but not readily used by the body. Nitrogen saturates body cells and tissues, which may cause evolved gas disorders.

(2) Oxygen (O_2): 21%. Second most plentiful gas. The human body uses O_2 to convert body fuels into energy.

(3) Other gases: 1%. Carbon dioxide (CO_2)-contained in the other 1% of gases and is essential to controlling respiration. (.03% of that 1% is CO_2.)

NOTE: NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

B. **ENABLING LEARNING OBJECTIVE**

ACTION:	Select the correct barometric pressure at sea level.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3-04-301.

1. Learning Step / Activity 1. Provide instruction on atmospheric pressure.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 10 mins
Media: Large Group Instruction

a. Atmospheric (barometric) pressure. Definition - the measurement of pressure exerted on the earth's surface from the gases and water in the atmosphere.

b. It is an observable characteristic that can be expressed in PSI, mm/Hg, inches of Hg, or in feet as indicated by an altimeter.

c. The percentage of Nitrogen (78%), Oxygen (21%), and Other gases (1%) in the atmosphere remains constant but pressure decreases with altitude. This decrease in pressure is responsible for most physiological problems in flight.

d. Standard sea level atmospheric pressure is 760mm/Hg. At 18,000 feet this atmospheric pressure is reduced to 380mm/Hg or one-half the pressure found at sea level. The chart shows other significant altitudes and atmospheric pressure reductions.

ALTITUDE	PRESSURE	
FEET	mm/Hg	ATMOSPHERES
18,000	380	½
34,000	190	¼
48,000	95	1/8
63,000	47	1/16

NOTE: Point out the lethality of Armstrong's Line at 63,000 feet.

e. Dalton's Law of partial pressure.

(1) Definition - the pressure exerted by a mixture of gases is equal to the sum of the partial pressures of each gas in the mixture.

NOTE: While the law states that atmospheric pressure is the sum of pressures of the gases in it, it also means that if the total pressure is decreased, the pressure of each gas must also decrease.

(2) Significance.

(a) The total atmospheric pressure exerted on the body decreases with altitude.

(b) The partial pressure of oxygen decreases with increased altitude.

(c) The amount of O_2 in a given volume of air decreases with altitude.

NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

C. ENABLING LEARNING OBJECTIVE

ACTION:	Identify the components of the circulatory system that transport oxygen throughout the human body.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301

1. Learning Step / Activity 1. Provide instruction on the circulatory system.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 20 mins
Media: Large Group Instruction

a. Functions of the circulatory system.

(1) Transport oxygen and nutrients (fuels) to cells throughout the body.

(2) Transport metabolic waste products to organ removal sites.

(3) Assists in temperature regulation.

b. Components of the circulatory system.

(1) Arteries - vessels that transport oxygenated blood from the heart to the body.

(2) Veins - vessels that transport deoxygenated blood from the body to the heart.

(3) Capillaries.

(a) Connect arteries to veins.

(b) Contact most tissues of the body transferring O_2, nutrients CO_2, and waste products between the cells and blood.

(c) Walls of the capillaries are one cell thick.

(d) Gas diffusion takes place between the body tissues and the blood.

c. Components and functions of blood – The average individual has 10 pints of blood which is approximately 5% of total body weight.

(1) Plasma: 55% of whole blood.

(a) Fluid part of the blood composed mainly of salt, water, and proteins.

(b) One of its important functions is to transport CO_2 in the blood.

(2) White blood cells (WBCs or leukocytes).

(a) Differ from red blood cells in that they contain no hemoglobin.

(b) Main function is to fight infection or inflammation.

(3) Platelets (Thrombocytes).

(a) Small irregular shaped bodies produced by the bone marrow.

(b) Aid in blood coagulation and maintaining the circulatory system.

(4) Red blood cells (RBCs or erythrocytes).

(a) Have an iron-containing compound, hemoglobin, which is responsible for the O_2 uptake of these cells.

(b) Transport approximately 98.5% of all O_2 in the body; the rest is transported in solution within the plasma.

(c) Bright red color of arterial blood results from the combination of O_2 with hemoglobin; darker color of venous blood reflects a hemoglobin that has no O_2 attached to it.

(d) Produced in the bone marrow and the number RBCs that an individual has depends largely on their environment. Such factors as the altitudes at which a person lives and whether a person smokes will influence RBC reproduction.

<u>NOTE</u>: Persons living above 10,000 feet can have as many as 30% more RBCs than an individual living at sea level.

NOTE: NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

D. ENABLING LEARNING OBJECTIVE

ACTION:	Select the functions and types of respiration.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301.

1. Learning Step / Activity 1. Provide instruction on the respiratory system.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 10 mins
Media: Large Group Instruction

a. Respiration. Definition - process by which a living organism exchanges gases with its environment.

b. Functions.

(1) Provide oxygen to the cells of the human body.

(2) Remove carbon dioxide from the cells of the human body.

(3) Assists in maintaining body temperature.

(4) Assists in maintaining body acid-base balance.

c. Types of respiration (external and internal).

(1) External respiration - lungs are ventilated during inhalation and exhalation, and gases are transferred through the lungs into the blood stream.

(a) Phases of external respiration - the respiratory cycle is an involuntary process that continues unless a conscious effort is made to control it. There are two phases of external respiration:

1. Active phase – the movement of air into the lungs (inhalation) is known as the active phase. During inhalation the chest wall expands and the diaphragm moves downward creating an area of lower pressure inside the lungs. With a higher pressure outside the lungs the law of gaseous diffusion takes place and the lungs fill with air.

2. Passive phase – the movement of air from the lungs (exhalation) is known as the passive phase. During exhalation the diaphragm relaxes and the chest walls contract increasing pressure inside the lungs. Once the glottis is opened, the pressure causes the air to rush out, releasing CO_2 into the atmosphere.

NOTE: Pressure breathing causes a reversal of the active and passive phases of respiration.

(b) Components of the external respiratory system.

1. Oral-nasal passage.

a. Includes the mouth and nasal cavities.

b. Nasal cavity contains many fine, ciliated hair cells which filter particles from the air upon inhalation. Therefore, air that enters through the nasal cavity is cleaner than air that enters through the mouth.

2. Pharynx.

a. Back of the throat and is connected to oral-nasal cavity and the trachea.

b. Humidifies and warms the air entering the respiratory system.

3. Trachea (Windpipe).

a. Tube through which air moves down into the bronchi.

b. From here, air continues to move down through the bronchi and increasingly smaller passages, or ducts, until it reaches the alveoli.

c. Also aids in expulsion or swallowing of mucus moved there by cilia.

(2) Internal respiration - gases are transported to and from body tissues by the blood. Chemical changes take place within the alveoli and tissue cells to metabolize the oxygen.

(a) Alveoli.

1. Small sacs surrounded by a network of capillaries.

2. There are approximately 300 million alveoli in a pair of human lungs.

3. Actual site of oxygen and carbon dioxide exchange between the respiratory and circulatory systems.

(b) Law of Gaseous Diffusion - this law states that a gas moves from an area of high pressure to an area of lower pressure.

(c) Blood gas exchange.

1. When O_2 reaches the alveoli, it crosses a thin cellular barrier and moves into the capillary to reach the RBC. As the O_2 enters the alveoli, it has a partial pressure (PO_2) of about 100mm/Hg. Within the blood the PO_2 of the

venous blood is about 40mm/Hg. As the blood flows through the capillary the O_2 moves from the area of high pressure within the alveoli to the area of lower pressure within the blood. Therefor O_2 saturation of RBCs takes place.

2. CO_2 diffuses from the blood to the alveoli in the same manner. The PO_2 in the venous blood is around 46mm/Hg in the alveoli. As the blood moves through the capillaries, the CO_2 moves from the high PCO_2 in the capillaries to an area of lower PCO_2 in the alveoli. The CO_2 is then exhaled during the next passive phase of respiration (exhalation).

NOTE: The exchange of O_2 and CO_2 between tissue and capillaries occurs the same as it does between the alveoli and capillaries.

3. The amount of O_2 transferred across the alveolar-capillary membrane into the blood depends primarily on the alveolar pressure of O_2 in relation to the venous pressure of O_2. O_2 transport in the blood is a pressure dependent phenomena.

4. This pressure differential is critical to the crewmember, because O_2 saturation in the blood decreases as altitude increases due to the decreasing partial pressure of oxygen in the atmosphere.

5. This decrease in O_2 saturation can lead to hypoxia.

d. Control of respiration.

(1) Controlled by the respiratory centers in the pons and medulla oblongata (lower brain).

(2) The uptake of O_2 and CO_2 takes place through extensive chemical changes in the hemoglobin and plasma of the blood.

(3) If the chemical pathways are disrupted, the chemical balance of the body changes.

(4) Normal pH level in the body is approximately 7.4 (slightly alkaline).

(5) During respiration, the CO_2 elevates, the acidity level increases, and the pH value lowers to less than 7.4.

(6) Conversely, too little CO_2 causes the blood to become more alkaline and the pH value to rise.

(7) Since the human body maintains equilibrium within narrow limits, any shift in the blood pH and CO_2 levels is sensed by the respiratory center of the brain.

(8) When unusual levels occur, chemical receptors trigger the respiratory process to help return the CO_2 and pH level to normal limits.

NOTE: NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

E. ENABLING LEARNING OBJECTIVE

ACTION:	Match the types of hypoxia with their respective causes.
CONDITIONS:	Given a list of hypoxia types and a list of hypoxia causes.
STANDARDS:	IAW FM 3.04-301.

1. Learning Step / Activity 1. Provide instruction on hypoxia.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 40 mins
Media: Large Group Instruction

a. Hypoxia. Definition - a condition that results from an insufficient amount of oxygen (O_2) in the body.

NOTE: Point out hypoxia can occur at any altitude and it is additive among the types listed below.

b. Types of hypoxia.

(1) Hypemic hypoxia - caused by a reduction in the O_2-carrying capacity of the blood. Anemia and blood loss are the most common cause of this type. Carbon monoxide from smoking and exhaust fumes are potentially dangerous to the aviator. Nitrates and sulfa drugs also cause this type by forming compounds with hemoglobin that block its ability to attach O_2 for transport.

(2) Stagnant hypoxia - reduction in systematic blood flow or regional blood flow. Such conditions as heart failure, shock and the venous pooling of blood encountered during positive-G maneuvers predispose the individual to stagnant hypoxia. In addition, environmental extremes, prolonged sitting and restrictive clothing can produce local stagnant hypoxia.

(3) Histotoxic hypoxia - results when there is interference with the use of O_2 by body tissues. Alcohol, narcotics, carbon monoxide and certain poisons such as nicotine and cyanide interfere with the cells' ability to use an otherwise adequate supply of O_2.

NOTE: Carbon monoxide is a very dangerous chemical composition as it attacks the body’s blood and tissues simultaneously. Hemoglobin has an affinity for CO 200 times greater than O_2.

(4) Hypoxic hypoxia - occurs when there is insufficient O_2 in the air that is breathed or when conditions prevent the diffusion of O_2 from the lungs to the blood stream. This is the type that is most likely to be encountered at altitude. It is due to the reduction of the PO_2 at high altitudes. See the chart in paragraph d under ELO #2.

c. Signs and symptoms.

(1) Symptoms are observable by the individual air crewmember. They vary from one person to the next, and are therefore considered subjective in nature. Examples include, but are not limited to the following:

NOTE: Each person will usually experience similar symptoms each time hypoxia occurs.

(a) Air hunger or breathlessness.

(b) Apprehension (anxiety).

(c) Fatigue.

(d) Nausea.

(e) Headache.

(f) Dizziness.

(g) Hot and cold flashes.

(h) Euphoria.

(i) Belligerence (anger).

(j) Blurred vision.

(k) Tunnel vision.

(l) Numbness.

(m) Tingling.

(n) Denial.

(2) Signs are observable by the other air crew members and therefore, are considered objective in nature. Examples include but are not limited to the following:

(a) Increased rate and depth of breathing.

(b) Cyanosis.

(c) Mental confusion.

(d) Poor judgment.

(e) Loss of muscle coordination.

(f) Unconsciousness.

(g) Slouching.

d. Stages of hypoxia.

(1) Indifferent stage.

(a) Altitude - sea level to 10,000 feet (equivalent altitude with 100% O_2 - 34,000 to 39,000 feet) with ambient barometric pressure.

(b) Symptom – the only significant effect of mild hypoxia in this stage is that night vision deteriorates at about 4,000 feet. The retina of the eye and the central nervous system have a great requirement for oxygen. To begin compensating for this your heart and breathing rate increase at about 4000 feet to improve circulation to brain and heart.

(c) Decrease of visual sensitivity of up to 28% at 10,000 feet, and it varies among individuals.

(d) Hemoglobin saturation - 98% at sea level decreasing to 87% at 10,000 feet.

NOTE: Symptoms of hypoxia become evident at 87% hemoglobin saturation.

(2) Compensatory stage. The circulatory system, and to a lesser degree, the respiratory system, provide some defense against hypoxia in this stage. Examples are increases in pulse rate, systolic blood pressure, circulation rate, and cardiac output.

(a) Altitude--10,000 feet to 15,000 feet (equivalent altitude with 100% O_2 - 39,000 feet to 42, 000 feet) with ambient barometric pressure.

(b) Symptoms.

CAUTION: Failure to recognize symptoms and take corrective action may result in an aircraft mishap.

1. Impaired efficiency.

2. Drowsiness.

3. Poor judgment.

4. Decreased coordination.

(c) Hemoglobin saturation - 87% to 80%.

(3) Disturbance stage. In this stage, the physiological responses can no longer compensate for the O_2 deficiency.

(a) Altitude - 15,000 feet to 20,000 feet (equivalent altitude with 100% O_2 - 42,000 feet to 44,800 feet) with ambient barometric pressure.

(b) Symptoms.

CAUTION: Failure to recognize symptoms and take corrective action may result in an aircraft mishap.

1. Sensory.

a. Vision - peripheral and central vision are impaired and visual acuity is diminished.

b. Touch and pain - diminished or lost.

c. Hearing - one of the last senses to be lost.

2. Mental - intellectual impairment is an early sign that often prevent an individual from recognizing disabilities.

a. Memory.

b. Judgment.

c. Reliability.

d. Understanding.

e. Decision making/problem solving.

3. Personality - may be a release of basic personality traits and emotions as with alcohol intoxication.

a. Euphoria.

b. Aggressiveness.

c. Overconfidence.

d. Depression.

4. Performance (psychomotor functions).

a. Coordination.

b. Flight control.

c. Speech.

d. Handwriting.

(c) Signs.

1. Hyperventilation.

2. Cyanosis.

(d) Hemoglobin saturation - 65-80%.

(4) Critical stage. Within 3 to 5 minutes, judgment and coordination deteriorate.

(a) Altitude - 20,000 feet and above (equivalent altitude with 100% O_2 - 44,800 feet and above) with ambient barometric.

(b) Signs.

1. Loss of consciousness.

2. Convulsions.

3. Death.

(c) Hemoglobin saturation--less than 65%.

WARNING: When hemoglobin saturation falls below 65%, serious cellular dysfunction occurs; and if prolonged, can cause death.

e. Factors modifying hypoxia symptoms.

NOTE: The factors increasing the chance of hypoxia are crucial in the academic development of the new aviator.

(1) Pressure altitude - determines the PO_2 in the lungs.

(2) Rate of ascent - at rapid rates, high altitudes can be reached before serious symptoms are noticed.

(3) Time at altitude (exposure duration) - usually the longer the duration of exposure, the more detrimental the effect of hypoxia. The higher the altitude, the shorter the exposure time required before hypoxia symptoms occur.

(4) Temperature - exposure to cold weather extremes reduces the tolerance to hypoxia by the natural increase in the metabolic workload. Therefore, hypoxia may develop at lower altitudes than usual.

(5) Physical activity - when physical activity increases, the body demands a greater amount of O_2. This increased O_2 demand causes a more rapid onset of hypoxia.

(6) Individual factors - an individual's susceptibility to hypoxia is greatly influenced by metabolic rate, diet, nutrition, and emotions (probably most inconsistent factor).

(7) Physical fitness - an individual who is physically conditioned will normally have a higher tolerance to altitude problems than one who is not. Physical fitness raises an individual's tolerance ceiling.

(8) Self-imposed stresses - smoking and alcohol increase an individual's physiological altitude and therefore reduces their tolerance ceiling.

f. Expected Performance Time (EPT) - The time a crewmember has from the interruption of the O_2 supply to the time when the ability to take corrective action is lost.

(1) The EPT varies with the altitude at which the individual is flying.

ALTITUDE	EPT
FL 500 & Above	9-12 seconds
FL 430	9-12 seconds
FL 400	15-20 seconds
FL 350	30-60 seconds
FL 300	1-2 minutes
FL 280	2½-3 minutes
FL 250	3-5 minutes
FL 220	8-10 minutes
FL 180	20-30 minutes

(2) Physical exertion results in a greater demand for O_2 and shortens the EPT.

(3) EPT for a crewmember flying in a pressurized cabin is reduced approximately one-half following loss of pressurization such as in a rapid decompression (RD).

g. Prevention of hypoxia (hypoxic).

(1) Limit time at altitude (AR 95-1, pg. 32, para. 8-7).

(2) Use supplemental O_2.

(3) Use pressurized cabin.

(4) Minimize self-imposed stressors.

h. Treatment of hypoxia.

(1) 100% O_2.

(2) Descend to a safe altitude (below 10,000ft at a minimum).

NOTE: NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

F. **ENABLING LEARNING OBJECTIVE**

ACTION:	Select thesymptoms and treatment of hyperventilation.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301 and Fundamentals of Aerospace Medicine.

1. Learning Step / Activity 1. Provide instruction on hyperventilation.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 10 mins
Media: Large Group Instruction

a. Hyperventilation - Definition - an excessive rate and depth of respiration leading to abnormal loss of CO_2 from the blood.

b. Causes.

(1) Emotions.

(a) Fear.

(b) Apprehension.

(c) Excitement.

(2) Pressure breathing.

(3) Hypoxia.

c. Symptoms--similar to those of hypoxia.

(1) Tingling sensations.

(2) Muscle spasms.

(3) Hot and cold sensations.

(4) Visual impairment.

(5) Dizziness.

(6) Unconsciousness.

d. Significance of hyperventilation.

(1) Can incapacitate a healthy crewmember.

(2) Can be confused with hypoxia.

e. Prevention.

(1) Don't panic.

(2) Control rate and depth of respiration.

f. Distinguishing between hyperventilation and hypoxia.

(1) Above 10,000 feet--assume hypoxia and treat accordingly.

(a) 100% O_2--if available.

(b) Descend to a safe altitude.

(2) Below 10,000 feet--assume hyperventilation and treat accordingly. Voluntary reduction in rate and depth of respiration is necessary to accomplish this task. Reading or repeating a checklist in most cases can treat hyperventilation.

NOTE: NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

G. ENABLING LEARNING OBJECTIVE

ACTION:	Select the causes and tratment of an ear, sinus and tooth trapped gas dysbarism.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301.

1. Learning Step / Activity 1. Provide instruction on trapped gas dysbarism.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 20 mins
Media: Large Group Instruction

a. Dysbarism - syndrome resulting from the effects, excluding hypoxia, of a pressure differential between ambient barometric pressure and the pressure of gases in the body. Also referred to as disorders.

b. Trapped gas dysbarism.

(1) Boyle's Law - The volume of a gas is inversely proportional to its pressure, temperature remaining constant.

(2) Dry gas conditions - Under dry gas conditions, the atmosphere is not saturated with moisture. Basically, under conditions of constant temperature and increased altitude, the volume of a gas expands as pressure decreases.

(3) Wet gas conditions - Gases within the body are saturated with water vapor. Under constant temperature and at the same altitude and barometric pressure, the volume of a wet gas is greater than the volume of a dry gas.

(4) Types of trapped gas disorders.

(a) Trapped gas disorders of the gastrointestinal tract.

1. Mechanism - the stomach and intestines contains gas, which expands during ascent causing gas pains.

2. Prevention.

a. Watch your diet (if a crewmember has difficulty relieving abdominal gas pains the diet should be adjusted to avoid gas-producing foods).

b. Avoid carbonated beverages and large amounts of water before going to altitude.

c. Don't chew gum during ascent.

d. Keep regular bowel habits.

3. Treatments.

a. Belching.

b. Passing flatus.

c. Descent to a lower altitude (if pain persists).

(b) Ear blocks.

1. Mechanism.

a. As the barometric pressure is reduced during ascent, the expanding air in the middle ear is intermittently released through the eustachian tube.

b. As the inside pressure increases, the eardrum bulges until an excess pressure of approximately 12 to 15mm/Hg is reached.

c. At this time, a small bubble of air is forced out of the middle ear and the eardrum resumes its normal position.

d. During ascent, the change in pressure within the ear may not occur automatically.

e. With the increase in barometric pressure during descent, the pressure of the external air is higher than the pressure in the middle ear and the eardrum is forced inward.

f. If the pressure differential increases appreciably, it may be impossible to open the eustachian tube. The eardrum could rupture because the eustachian tube can’t equalize the pressure.

2. Prevention.

a. The most common complaint of crewmembers is the inability to ventilate the middle ear.

b. This inability frequently occurs when the eustachian tube or its opening is swollen shut as the result of an inflammation or infection due to a head cold, sore throat, middle ear infection, sinusitis, or tonsillitis.

c. Unless absolutely necessary, crew members with colds or sore throats should not fly.

3. Treatment.

a. Stop descent of aircraft and attempt to clear by valsalva.

b. If the condition is not cleared, climb to altitude until cleared by pressure change or valsalva.

c. Reduce rate of descent and equalize ear/sinus frequently during descent.

(c) Sinus blocks.

1. Mechanism.

a. Like the middle ear, sinuses can also trap gas during flight.

b. Sinuses are air-filled, relatively rigid, bony cavities lined with mucus membranes.

c. Sinuses are connected with the nose by means of one or more small openings.

d. If the openings into the sinuses are normal, air passes into and out of these cavities without difficulty and pressure equalizes.

e. If these openings become obstructed it may become difficult or impossible to equalize the pressure.

2. Prevention.

a. Avoid flying with a cold or congestion.

b. Perform the Valsalva maneuver more frequently.

3. Treatment – treat a sinus block the same as you would treat an ear block.

(d) Barodontalgia (trapped gas disorders of the teeth).

1. Mechanism - change in barometric pressure can cause a toothache.

EXAMPLE: Air may be trapped in the tooth by recent dental work. Air under the filling material will expand during ascent causing pain.

2. Prevention--avoid flying following dental restoration or when in need of restoration.

3. Treatment - descent usually brings relief.

4. Referred pain.

a. Nerve endings for sinuses and the upper teeth are in close proximity in the maxilla.

b. On occasion, the sinuses will block putting pressure or pain on the upper teeth.

c. Condition must be treated as a ear/sinus block.

NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

H. ENABLING LEARNING OBJECTIVE

ACTION:	Identify the types and treatments of evolved gas dysbarisms, which occurs with altitude.
CONDITIONS:	Given a list.
STANDARDS:	IAW FM 3.04-301 and Fundamentals of Aerospace Medicine.

1. Learning Step / Activity 1. Provide instruction on evolved gas dysbarism.

Method of Instruction: Conference / Discussion
Instructor to Student Ratio: 1:50
Time of Instruction: 20 mins
Media: Large Group Instruction

a. Evolved Gas Dysbarism (decompression sickness) - Occur as a direct result of a reduction in atmospheric pressure. As pressure decreases, gases dissolved in body fluids are released as bubbles. This will cause varied skin and muscle symptoms and possibly neurological symptoms.

b. Henry's Law - The amount of gas dissolved in a solution is directly proportional to the pressure of the gas over the solution. This is similar to gas being held under pressure in a soda bottle. When the cap is removed, the liquid inside is exposed to a lower pressure; therefore, gases escape in the form of bubbles. Nitrogen (N_2) in the blood behaves in the same manner.

c. Mechanism.

(1) Inert gases in body tissues (principally N_2) are in pressure equilibrium with the same gases in the atmosphere.

(2) When barometric pressure decreases, the partial pressures of atmospheric gases decrease proportionally, leaving the tissues temporarily supersaturated.

(3) Responding to the supersaturating, the body attempts to establish a new equilibrium by transporting the excess gas volume in the venous blood to the lungs.

(4) However, this is an inefficient system of removal and could lead to an evolved gas disorder.

d. Four types of evolved gas disorders.

WARNING: Evolved gas disorders are considered serious and medical treatment/advice must be sought immediately.

(1) Bends.

(a) Occurs when the N_2 bubbles become trapped in the joints. At the onset of bends, pain may be mild but it can become deep, gnawing, penetrating, and eventually intolerable.

(b) Severe pain can cause loss of muscular power of the extremity involved and, if allowed to continue, may result in bodily collapse.

(c) The larger joints, such as the knee or shoulder, are most frequently affected. The hands, wrists, and ankles are also common sites.

(d) It may occur in several joints simultaneously and worsen with movement.

(2) Paresthesia (creeps/tingles).

(a) Tingling and itching sensations on the surface of the skin are the primary symptoms of parathesia. It is caused by N_2 bubbles forming along the nerve tracts leading to the affected areas.

(b) A mottled red rash may appear on the skin.

(3) Chokes.

(a) Symptoms occurring in the thorax are probably caused by innumerable small N_2 bubbles that block the smaller pulmonary vessels.

(b) At first, a burning sensation is noted under the sternum. As the condition progresses, the pain becomes stabbing with deep inhalation. The sensation in the chest is similar to what one experiences after completing a 100-yard dash. Short breaths are necessary to avoid distress.

(c) There is an uncontrollable desire to cough, but the cough is ineffective and nonproductive.

(d) Finally, there is a sensation of suffocation; breathing becomes more shallow and the skin has a bluish coloration.

(4) CNS disorder.

(a) In rare cases when aircrews are exposed to high altitude, symptoms may indicate that the brain or the spinal cord is affected by N_2 bubble formation.

(b) The most common symptoms are visual disturbances, which vary from blind spots to the flashing or flickering of a steady light.

(c) Other symptoms may be a dull-to-severe headache, partial paralysis, the inability to hear or speak, and the loss of orientation.

(d) Paresthesia, or one-sided numbness and tingling, may also occur.

e. Influential factors - evolved gas disorders do not happen to everyone who flies. Certain factors tend to increase the chance of evolved gas problems and reduce the altitude at which problems can occur.

(1) Rate of ascent - the more rapid the rate of ascent, the greater the chance that evolved gas disorders will occur; the body does not have time to adapt to the pressure changes.

(2) Altitude – there is no reliable evidence for the occurrence of DCS with altitude exposures below 18,000 feet, as altitudes increase so does the rate of incidence.

(3) Age - evidence suggests that individuals in their mid-forties are more susceptible than those in their early twenties.

(4) Exercise – the effect of exercise on the incidence of DCS is equivalent to increasing the exposure altitude 3,000-5,000 feet.

(5) Duration of exposure - the longer the exposure, especially above 18,000 feet, the more likely that evolved gas disorders will occur.

(6) Repeated exposure - the more often individuals are exposed to altitude above 18,000 feet (without pressurization), the more they are predisposed to evolved gas disorders.

(7) Gender/Body build – due to emotional and political factors, studies are limited and are therefore inconclusive regarding gender and the incidence of DCS. In addition there is no scientific validation that obesity increases the rate of incidence of DCS.

f. Prevention.

(1) Denitrogenation (prebreathing 100% O_2 is required for flights exceeding 20,000 feet).

(2) Flying a pressurized aircraft, if possible.

(3) Limit time at high altitude.

g. Treatment.

(1) Descend to ground level.

(2) 100% O_2.

(3) Seek medical advice/assistance.

(4) Compression therapy.

h. Aircrew restrictions.

(1) In accordance with (IAW) AR 40-8, crewmembers will not fly for 24 hours after SCUBA diving.

(2) During SCUBA diving, excessive N_2 uptake by the body occurs in using compressed air.

(3) Flying at 8,000 feet within 24 hours after SCUBA diving at 30 feet subjects an individual to the same factors a non-diver faces when flying unpressurized at 40,000 feet. N_2 bubbles form in the circulatory system.

NOTE: Conduct a check on learning and summarize the learning activity.

CHECK ON LEARNING: Conduct a check on learning and summarize the ELO.

SECTION IV. SUMMARY

Method of Instruction: Conference / Discussion Instructor to Student Ratio is: 1:50 Time of Instruction: 5 mins Media: Large Group Instruction

Check on Learning

a. Solicit student questions and explanation.

b. Questions and answers.

QUESTION: Which of the Physiological Zones of the atmosphere is lethal to the human system?

ANSWER: Space Equivalent Zone.

QUESTION: Select the atmosphere in which total atmospheric pressure is reduced by 1/2 the pressure found at sea level.

ANSWER: 18,000.

QUESTION: Select the component of blood responsible for transporting the majority of the blood in the human system.

ANSWER: Red Blood Cell.

QUESTION: Select the active phase of respiration.

ANSWER: Inhalation.

QUESTION: Match the type of hypoxia with its respective cause.

ANSWER: Hypemic--caused by a reduction of the oxygen carrying capability of the blood such as blood loss, carbon monoxide poisoning, and smoking.

Stagnant--reduction in systematic or regional blood flow such as heart failure, shock and venous pooling of blood.

Histotoxic--results when there is interference with the use of oxygen by the body tissues caused by alcohol, narcotics, carbon monoxide and nicotine.

Hypoxic–-occurs when there is insufficient oxygen in the air that is breathed or when condition prevent the diffusion of oxygen from the lungs to the blood stream.

QUESTION: Select the symptoms of hyperventilation.

ANSWER: Tingling sensations, muscle spasms, hot and cold sensations, visual impairment, dizziness, unconsciousness.

QUESTION: Identify the correct treatment of a ear or sinus block.

ANSWER: Stop the descent of the aircraft and attempt to clear by valsalva, if unable to clear ascend the aircraft until cleared by pressure or valsalva, reduce rate of descent and clear ears frequently on descent.

QUESTION: Identify the type of evolved gas dysbarism which occurs in body joints.

ANSWER: The bends.

c. Correct any misunderstandings.

3. TRANSITION TO THE NEXT LESSON. Next you will have a one hour class on vibrations. This will enhance your understanding of the human system in rotary wing flight.

Review / Summarize Lesson

SECTION V. STUDENT EVALUATION

Testing Requirements	**NOTE:** Describe how the student must demonstrate accomplishment of the TLO. Refer student to the Student Evaluation Plan. a. The ELOs for this lesson will be tested during your final examination. b. Final examination will be Pass/Fail. c. IERW is presently restricted from the Altitude Chamber so a practical demonstration is unavailable.
Feedback Requirements	**NOTE:** Feedback is essential to effective learning. Schedule and provide feedback on the evaluation and any information to help answer students' questions about the test. Provide remedial training as needed. a. Each student will be provided feedback concerning the mastery of this lesson plan TLO as part of the preparatory requirements of the final examination. b. Remedial training is available by appointment.

Appendix A - Viewgraph Masters (N/A)

Appendix B - Test(s) and Test Solution(s) (N/A)

Appendix C - Practical Exercises and Solutions (N/A)

Appendix D - Student Handouts (N/A)